Lessons learned from BaBar Silicon Vertex Tracker, limits and future perspectives of the detector

Abstract

The Silicon Vertex Tracker (SVT) of the BaBar experiment at PEPII is described. This is the crucial device for the measurement of the position of the B meson decay vertices to extract CP-asymmetries. It consists of five layers of double sided AC-coupled Silicon strip detectors, read out by a full-custom integrated circuit, capable of simultaneous aquisition, digitization and transmission of data. It represents the core of the BaBar tracking system, providing position measurements with a precision of 10μm (inner layers) and 30μm (outer layers). The relevant performances of the SVT are presented, and the experience acquired during the construction, installation and the first five years of data-taking is described. Innovative solutions are highlightened, such as the sophisticated alignment procedure, imposed by having the silicon tracker integrated in the beam-line elements and mechanically separated from the other parts of BaBar. The harshness of the background conditions in the interaction region required several studies on the radiation damage of the sensors and the front-end chips, whose results are presented. Over the next six years the luminosity is predicted to increase by a factor three, leading to radiation and occupancy levels significantly exceeding the detector design. Extrapolation of future radiation doses and occupancies is shown together with the expected detector performance and lifetime. Upgrade scenarios to deal with the increased luminosity and backgrounds are discussed.

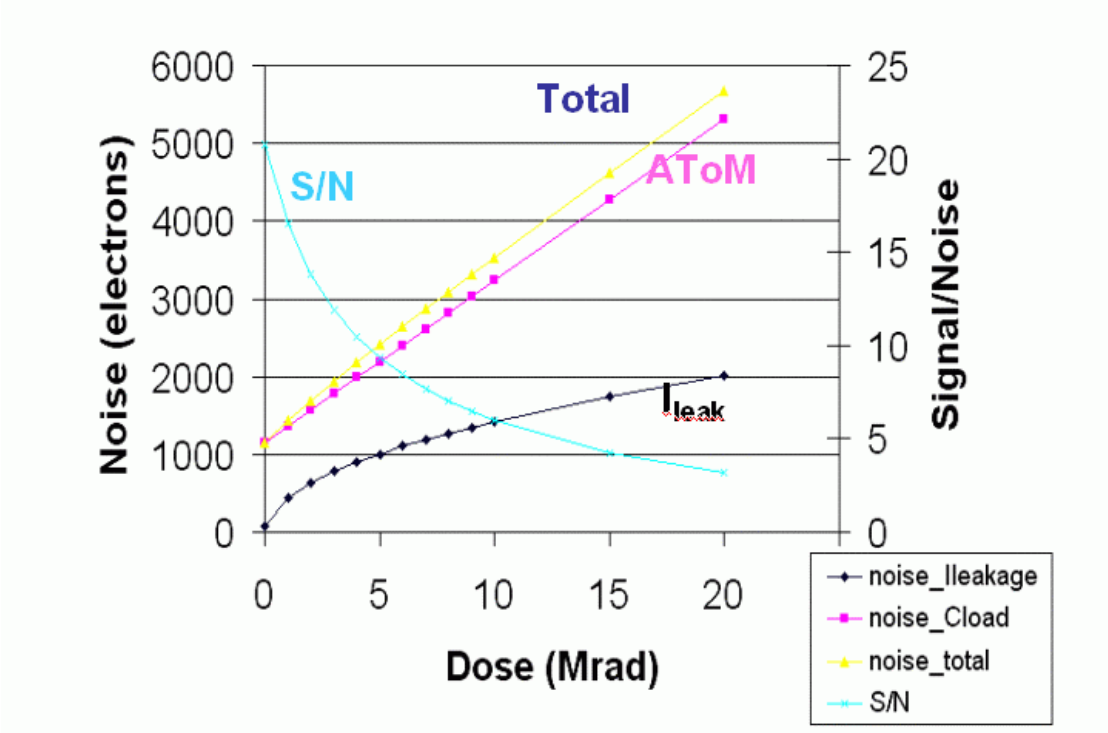
Summary

In this presentation the BaBar Silicon Vertex Tracker will be introduced, with a discussion of the specific solutions in the design of the detector and the general performances after the experience of the first five years of running. A brief description of SVT is aimed at enlightening the innovative features with respect to similar existing detectors: only active material on particle trajectories, arch-shaped modules in the outer layers to minimize multiple scattering effects, signal digitization performed with the time-over-threshold method in a full custom integrated circuit. Then the SVT performances will be discussed not only in terms of spatial resolutions and track reconstruction but also of particle identification through measurement of track energy loss due to ionization. The challenging alignment procedure will be described, with special attention to the unprecedented technical difficulties coming from the five-layer design and the freedom of movement inside the BaBar detector imposed by seismic concerns; the level of detail achieved, including corrections for non-planarity effects in the individual silicon modules, will be presented.

The second part of the talk will be devoted to the extrapolation of the SVT performance over the next six years, during which the luminosity will increase by a factor three. The expected radiation dose and the increase in detector occupancy will be extrapolated for the different years, based on the future beam currents, luminosity and beam-beam effects.

Several studies have been made to quantify the impact of radiation damage and occupancy on the SVT performance, for both the silicon sensors and the front-end

electronics. In the case of the sensors, the increase in leakage current, the change in the depletion voltage and the drop in charge collection efficiency have been measured using test-beams with 1 GeV electrons at Elettra (Trieste, Italy).
In the case of the front-end chips, a program of irradiations with Co60 sources al LBNL (Berkeley) and SLAC (Stanford) and with 1 GeV electrons at Elettra (Trieste) has provided information on the degradation in the chip performance as a function of the integrated dose.
The conclusions of the studies on the sensors and the front-end chips will be presented and compared with the measurements on the installed detector. These results will be applied to the dose and occupancy extrapolations until 2010, allowing a study of the future SVT performance and the impact on the BaBar physics program.
Finally, the present limits of the detector with respect to the increased luminosity and backgrounds will be discussed and possible upgrade scenarios will be shown.



Extrapolation as a function of dose of the different noise components in the SVT (left scale) and the expected evolution of the Signal/Noise ratio (right scale).